INTERCOOLED TURBINE BLADE COOLING AIR FEED SYSTEM

FIELD OF THE INVENTION

This invention relates to gas turbines and, more particularly, to a concept for efficiently reducing the temperature of air used to cool high-temperature turbine rotor blades.

BACKGROUND OF THE INVENTION

It is well understood that turbine inlet temperature is a major determinant of the specific power available from a gas turbine. However, current turbines are limited in inlet temperature by the physical properties of the materials used to construct the turbines. To permit turbines to operate at gas stream temperatures which are higher than the temperatures which conventional materials can normally tolerate, considerable effort has been devoted to the development of sophisticated methods of turbine cooling.

In early gas turbine engine designs, cooling of high-temperature components was limited to transferring heat to lower-temperature parts by the method of conduction, and air-cooling technology was limited to passing relatively cool air across the face of the turbine rotor disks. In order to take advantage of the potential performance improvements associated with higher turbine inlet temperatures, modern turbine cooling technology utilizes air-cooled hollow turbine nozzle vanes and rotor blades to permit operation at inlet gas temperatures in excess of 2000° F. Various techniques have been developed to cool these hollow blades and vanes. These incorporate two basic forms of air cooling, used either singly or in combination, depending upon the level of gas temperatures encountered and the degree of sophistication permissible. These basic forms of air cooling are known as convection and film cooling.

However, the benefits obtained from sophisticated air-cooling techniques are at least partially offset by the extraction of the necessary cooling air from the propulsive cycle. The conventional source of coolant for a high-pressure turbine is air which is bled off the compressor portion of the gas turbine engine and is routed to the hollow interior of the turbine blades. The quest for thermal efficiency has caused an increase in the compressor delivery air temperature. However, the compressor air, having a temperature much less than that of the turbine flow path gas stream, absorbs heat from the turbine blades to maintain the blades at an acceptable temperature. When this heated cooling air leaves the turbine blades, perhaps as a coolant film, this heat energy is lost to the propulsive cycle since the cooling air is normally mixed with the exhaust gases and ejected from an engine nozzle. More particularly, the air that is bled from the compressor and used as cooling air for the turbine rotor blades has had work done on it by the compressor. However, because it is normally reintroduced into the flow path gas stream downstream of the turbine nozzle, it does not return its full measure of work to the cycle as it expands through the turbine. Additionally, the reintroduction of cooling air into the gas stream produces a loss in gas stream total pressure. This is a result of the momentum mixing losses associated with injecting a relatively low-pressure cooling air into a high-pressure gas stream. The greater the amount of cooling air which is routed through the turbine blades, the greater the losses become in the propulsive

cycle. Thus, while turbine blade cooling has inherent advantages, it also has associated therewith certain inherent disadvantages which are functions of the quantity of cooling air used in cooling the turbine rotor blades.

It will, therefore, be appreciated that engine performance can be increased by reducing the amount of cooling air required by the turbine rotor blades. One system for accomplishing this goal was disclosed in U.S. Pat. No. 4,137,705 to Andersen et al. In accordance with that teaching, an aircraft gas turbine engine is provided with a turbine wherein the rotor disk bears a plurality of hollow, air-cooled turbine blades. Cooling air is bled from the compressor portion of the engine and routed radially inwardly into a compact heat exchanger connected to and rotatable with the compressor. Heat which has been introduced into the cooling air through the compression process is extracted within the heat exchanger by engine lubricating oil which is routed through the heat exchanger and into heat exchange relationship with the cooling air. The cooled cooling air is then directed from the heat exchanger and through the turbine rotor blades to provide improved cooling thereof. The lubricating oil is that which performs the usual engine lubrication function so that an additional coolant need not be carried by the aircraft. Subsequently, this oil is cooled by engine fuel or the fan bypass stream airflow (in a gas turbofan engine) in a stationary heat exchanger relatively remote from the turbine. The use of the fuel as the final heat sink results in a partially regenerative engine in that most of the heat removed from the compressed air is reintroduced into the engine cycle as heated engine fuel.

SUMMARY OF THE INVENTION

It is an object of the present invention to improve upon the teaching of U.S. Pat. No. 4,137,705 by eliminating the lubricating oil from the heat exchange cycle and performing the coolant heat exchange or heat rejection external to the engine, thus providing scope for efficient heat exchanger design, including modulation of coolant temperature and easy access for inspection and replacement. In particular, it is an object of the invention to provide direct or indirect heat exchange between cooling air bled from the high-pressure compressor and the fuel for the engine.

Another object of the invention is to enhance the efficiency and increase the power available from a core engine of predetermined size.

A further object of the invention is to provide an aircraft gas turbine engine in which the turbine rotor blades are cooled to withstand the high-temperature gases of combustion.

It is another object of the invention to reduce the amount of cooling air required by the turbine rotor blades by reducing the temperature of the cooling air passing therethrough in order to improve cooling effectiveness.

Yet another object is to provide an aircraft gas turbine engine wherein the work done by the compressor on that portion of the pressurized air used for turbine cooling is returned to the engine power cycle as useful energy.

Another object of the invention is to provide a mechanism for modulating the coolant temperature at lower power and lower fuel flows. In particular, to avoid overheating of the fuel at low fuel flows, the cooling air